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Roundtable Discussion

Videogame Mechanics in Games for Health

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Game mechanics have been identified as "methods invoked by agents for interacting with the game world."[1] They are elements of game play that provide a primary source of interactivity and structure how videogames proceed. Many kinds of game mechanics have been generated. Some provide fun or enjoyment, others may provide excitement or even suspense (i.e., emotional aspects of game play), whereas some are guided by principles of behavior change theory. Game mechanics that succeed in off-the-shelf entertainment videogames, however, may not work in serious games, such as games for health (G4H). Although game mechanics are key to a serious videogame's success, maintaining a balance between the serious intent of the game while keeping it fun, there has been little attention to game mechanics in the academic G4H literature. Several eminent games for health developers (academics and nonacademics) were asked to share their experiences in regard to game mechanics in the serious videogames they have developed.

Tom Baranowski: ***Please name and describe the G4H(s) you created and what health issue(s) they addressed.***

Debra Lieberman: I have contributed research, behavioral health principles, and game design strategies to videogames aimed at improving health behaviors for a variety of health topics dealing with healthy lifestyle, prevention issues, self-care, chronic condition self-management, and/or adherence to treatment plan.[2–10]

One of my early games, published in 1994, is "Packy & Marlon," an action/adventure game on the Super Nintendo [Nintendo®, Kyoto, Japan] platform designed to improve the diabetes self-management of children and adolescents who have type 1 diabetes.[2] In the game, Packy and his friend Marlon are diabetic elephants who arrive at diabetes summer camp only to discover that rats and mice have marauded the camp and scattered food and diabetes supplies throughout the camp's mountains, lakes, playgrounds, forests, and haunted cabins. Our heroes (there is an option for a single-player game or a two-player collaborative game) must gather the scattered items and fend off menacing rats and mice while they must also manage their own diabetes during four simulated days. Each day includes three meals and three snacks. With six food events per day over a 4-day period, the game has 24 levels of game play. Before each meal or snack, players must help their character use a meter to measure blood glucose and then give their character insulin in a fixed or variable dose, either two or four times a day. The game offers various insulin dosing options so that players can select the insulin regimen that most closely matches their own. Players guide their character to find diabetes supplies and the foods needed for healthy meals and snacks. Players follow recommended menus and use food exchanges to find equivalent foods (e.g., it is fine to eat an apple instead of the pear listed on the menu) in five major food groups to follow the menu successfully. The underlying game algorithm takes into account the insulin and food Packy or Marlon has had and generates a continuous log of the character's blood glucose levels (High, OK, or Low) over time, which is always available to review. The character is strongest and best able to win the game when blood glucose remains in the OK zone. The game aligns health goals with game goals by requiring players to manage their character's diabetes in order to maintain optimal health, which is essential to win the game. Players must control their character's blood glucose—by using the blood glucose meter before each meal and snack, taking insulin, and selecting the

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right foods—to be strong enough to carry out other non–health-related game goals. To find items and foods, overcome the rats and mice, and reach their destination, the characters climb, jump, glide, shimmy, swing, run, snorkel, and swim throughout the camp while avoiding various traps, enemies, creatures, ghosts, and perils.

Richard Buday: We've developed dozens of health behavior interventions and health learning applications over the past 15 years. Half were true videogames, that is, required skill, had rules, awarded points, ended in win/lose conditions, or allowed players to compete against other players for high scores. The games include: "Escape From Diab," a children's personal computer (PC) role-playing game (RPG) behavioral intervention targeting increased fruit/vegetable/water consumption and physical activity[11,12]; "Nanoswarm: Invasion From Inner Space," a PC RPG children's behavioral intervention targeting increased fruit/vegetable/water consumption and physical activity[12,13]; "Lunch Crunch 1 and 2," casual Web-based nutrition knowledge games for youth[14,15]; "Pyramid Pile Up" and "Pyramid Pile Up Plus," casual Web-based nutrition knowledge games for youth[16]; "Brain Gain," a casual Web-based nutrition and physical activity knowledge game for youth[17]; "Bubble Rubble," a casual Web-based physical activity knowledge game for youth[18]; "Juice Jumble," a casual Web-based beverage knowledge game for youth[19]; "Food Fury," a casual Web-based nutrition knowledge game for youth[20]; "Kitchen Quest," an iPad® [Apple, Cupertino, CA] nutrition knowledge game for youth[21]; and "Kiddio Food Fight," an iPhone® [Apple] vegetable parenting game for adults.[22]

Others were game-like experiences but didn't meet the true definition of a game. Examples include: "GEMS," a children's Web-based role-playing behavioral intervention targeting increased fruit/vegetable/water consumption and physical activity[23,24]; "Boy Scouts' Fit for Life Badge," a children's Web-based behavioral intervention targeting increased fruit/vegetable/water consumption and physical activity[25,26]; "Family Eats," a Web-based family makeover behavioral intervention targeting increased fruit/vegetable/water consumption and physical activity[27,28]; "Teen Choice," a Web-based animated behavioral intervention for teenagers using role modeling to increase fruit/vegetable/water consumption and physical activity[29,30]; "Squires Quest II," a children's Web-based role-playing behavioral intervention targeting increased fruit/vegetable/water consumption and physical activity[31,32]; "The Butterfly Girls," a children's Web-based role-playing behavioral intervention targeting increased fruit/vegetable/water consumption and physical activity[33]; "The Brewsters," a first-year health professions ethics course delivered as a softcover or ebook choose-your-own-adventure novel[34,35]; and "My Comfort Zone," a Web-based treatment decision support tool for recently diagnosed prostate cancer patients.[36,37]

Wei Peng: At Michigan State University's Games for Entertainment and Learning lab, we created "Olympus,"[38,39] a stealth exergame to promote physical activity among sedentary young adults. "Olympus" is a third-person, fantasy RPG that allows players to immerse themselves in the wondrous time of Ancient Greek history and myth. "Olympus" enhances the typical role-playing experience by getting the player off the couch. Through the use of a WiiMote [Nintendo] (accelerometer-based motion controller) and a dance pad, the player's corresponding physical actions in the real world drive the virtual actions of his or her avatar in the game world.

Lukas Zimmerli: We have created different games for lower- and upper-extremity rehabilitation (e.g., after stroke/spinal cord injury/cerebral palsy/traumatic brain injury) and for low-back-pain patients during therapy. Patients interact with the games through sensor information received from the joints of external orthoses (i.e., an external orthopedic appliance that assists or prevents spine or limb movement) or from wireless sensors attached to the back of patients. Examples for lower-extremity rehabilitation include exercises where patients navigate through virtual environments (using an external orthosis attached to their leg[40]), collecting objects that are randomly distributed while avoiding "enemy" objects. Examples for upper-extremity rehabilitation include puzzle games, where patients move pieces to the correct position.[40,41] Examples for low-back-pain rehabilitation include exercises where patients have to collect shells distributed within a cave by moving their pelvis.[41]

Brenda Wiederhold: Since the mid-1990s, we have been involved in creating simulations of both mental and physical health disorders, as well as utilizing simulations for stress management and for training medical personnel/first responders. Some of the games have been used to treat specific phobias (flying, driving, public speaking, etc.), panic disorder and agoraphobia, social phobia, and posttraumatic stress disorder (PTSD). We have also created games to help with acute pain during medical and dental procedures, chronic pain conditions, teen smoking prevention, and cognitive and physical rehabilitation after stroke or injury. Some examples include:

- *Teen smoking prevention game*—funded by the National Institute of Drug Abuse, NIH [National Institutes of Health], this game helps high school students increase knowledge about the negative health effects of smoking and works to improve their ability to find alternative activities to combat smoking urges. In our studies, student acceptance was high, primarily due to having content creation from the students themselves. In our experience, involving the end user in the design and development phases improves overall acceptability and performance.
- *Driver education game*—funded by the Centers for Disease Control and Prevention, this study supplemented classroom training to more effectively train teen driving skills and to provide assessment and immediate feedback of driving errors. Immediate feedback from teen users indicated that the interactivity allowed them to more effectively understand skill sets and build self-efficacy prior to approaching the real-life driving situation. This long-term study is investigating the ability of simulation training benefits to result in a reduction of moving violations, traffic accidents, DUIs [driving under the influences], and traffic-related fatalities.
- *School phobia/social phobia treatment using shared Internet worlds*—Children with school phobia, anger management, and social phobia were effectively treated with

shared simulation worlds. Both therapists and patients were able to navigate in shared gaming environments to treat social phobia. Immediate feedback was received, and patients were able to practice skill sets in real time. This same protocol was then adapted for treating adults with social phobia and fear of public speaking. Our goal is to treat individuals earlier in the life cycle to prevent long-term negative effects and to move increasingly towards prevention in at risk populations.

- *Driving games*—in collaboration with the FDA [Food and Drug Administration] and a major pharmaceutical firm, we have worked on projects to help qualify prescription medications prior to their approval for being sold in an over-the-counter status. In one particular study, the effects on driving abilities and cognition were assessed in a randomized controlled clinical trial.
- *Pain management*—funded by the National Institute of Drug Abuse, NIH, seven worlds were developed and tested for use in those undergoing painful medical and dental procedures. In a second funded study, prototypes were then ported from the PC and laptop to portable devices, allowing patients continued access to pain relief anytime/anywhere. A prototype was also developed to link activity with physiological relaxation/arousal. In our pilot study, even on a mobile platform, games can provide an effective supplement for chronic pain management.

Pamela Kato: I worked with some very talented teams in developing G4H. The game that most people know is "Re-Mission." "Re-Mission" (www.re-mission.net) is a game designed to address the primary outcome of medication compliance among adolescents and young adults with cancer. I have worked on serious games to improve patient safety by addressing human factors of stress management, teamwork, communication, and professionalism and also supervised students working on games to improve adherence to physical therapy among patients who have undergone knee surgery. I am working on other G4H that are currently protected by confidentiality agreements until they are publicly released later this year.

Tom Baranowski: ***What kind of game mechanics have you found successful in G4H?***

Debra Lieberman: A wide variety of game mechanics have been used to deliver game play experiences that motivate and maintain health behavior change, help train clinicians, or support diagnosis and treatment. Some games enable direct experience in a virtual world that rehearses cognitive or physical skills applicable in the actual world. For example, cognitive skills used repeatedly in a game can improve those skills in real-world contexts.[42] This could involve using game mechanics that require the player to ignore distractions, use visual discrimination skills to detect hidden objects in a complex display, or see and hear a presentation and reproduce the same sequence of events from memory, to name a few. Likewise, active games provide direct experiences that can train physical skills applicable to daily life, as players connect to a virtual world by using physical interfaces that detect touch and pressure or use camera-based interfaces that detect movement. For instance, some players learn how to dance with dance pad games, improve their balance with balance boards, and improve their physical coordination or cardiovascular fitness with exertion games. Many game mechanics can be used in cognitive games and active games, and the thread they often have in common is that they require players to learn and apply cognitive or physical skills in the game that they can then use in their own lives.

To teach skills for healthy lifestyle, prevention, and self-care, to enable rehearsal of the skills, to develop deeper understanding of cause-and-effect, and to change health-related attitudes and behaviors, simulation games and scenario-based games are especially effective. Players must solve problems and confront challenges in a virtual, simulated world in which they can influence events in consequential ways. A health simulation game can challenge players to maintain their character's health, prevent health threats, and solve current health problems while receiving immediate feedback about the success or failure of the choices they have made. Research has shown that health-related knowledge,[7] skills,[39] self-confidence,[43] and behaviors[2] can improve when players rehearse skills in a simulation game and, in the process, develop new attitudes, emotional responses, risk perceptions, self-concepts, and social connections, all of which can potentially strengthen motivation for behavior change.[5,9,10]

To motivate engagement in game challenges and increase expenditure of effort, the game mechanics of collaborative game play and teamwork add a social component that can make players feel strongly committed to remaining in the game in order not to disappoint their partner or team. Collaborative learning and teamwork also involve strategizing with one's partner and teaching and coaching one's partner, which are well-documented, powerful ways to learn[44] and, for players with health problems or chronic conditions, are ways to increase communication and social support related to their health issues.[2]

To strengthen perceptions of personal risk and susceptibility to a health problem, which can motivate health behavior change,[10] games can use role modeling and self-modeling. Role modeling is a component of Social Cognitive Theory[45] and occurs in videogames when players see characters similar to them demonstrating behaviors that are rewarded or punished. Role modeling involves both observational learning—simply seeing the behaviors of role models and learning through observation—and learning about the behaviors that are likely to lead to desirable or undesirable outcomes. People will be more likely to carry out the behaviors they have observed that are rewarded and lead to desirable outcomes. If the role model character experiences negative health consequences after engaging in an unhealthy behavior or failing to engage in a healthy behavior, players may feel that, like the negative role model character, they too are at higher risk than they originally believed and may change their own behaviors to try to avoid experiencing those consequences.[9] Self-modeling can occur when game players play the role of a character or avatar that is similar to them in behaviors or appearance or demographic characteristics, or with whom they identify. Players control their own character, but a role-modeling process occurs nonetheless, and sometimes players develop new self-concepts, believing they actually have the characteristics, goals, and likely outcomes of their game character.[46] More research is needed to

understand processes of self-modeling and how they differ from observational learning with role models.

Progress tracking of videogame characters' health measures, such as blood glucose (diabetes) or peak flow (asthma), based on players' decisions in the game, is analogous to the real-life tracking of personal health measures that are critically important in the daily regimen of people with chronic conditions. We used character progress tracking in "Packy & Marlon" to provide game play feedback and also to get players into the habit of checking meter readings, to help enhance their skills and self-efficacy for diabetes progress tracking in their own lives. We used epistemic learning, which gives players the opportunity to make decisions and take actions in a virtual game world that resembles the scenarios and actions they encounter every day.

Games can now use sensors to track players' own heart rate, steps taken, blood pressure, blood glucose, and other vital signs. These measures can be inputs into a health game, enabling players to use their own health behaviors and health data to achieve game challenges. To win the game, their measures must maintain or move in a healthy direction.

These are just a few of the game mechanics I have used, based on behavioral health principles and multimedia instructional design principles that are well researched, are known to influence people cognitively, emotionally, socially, and/or physically, and as a result can lead to improved health behaviors and outcomes.

Richard Buday: Mechanics that are both fun and appear natural to the game's flow are usually the best. In one of our projects, we wanted players to distinguish between healthy foods and those that appeared healthy, but really weren't. Making healthy choices is not a fun task *per se*. Taken literally, the activity could be presented didactically, which would break the player's feeling of presence in a game. Instead, we gave the player controls for running around a three-dimensional warehouse to select boxes of real fruit or fruit-like foods, made it time-based, and awarded points for correct choices. We also wove the activity tightly into the game's storyline. Everything made sense, and players loved it.

Wei Peng: The game mechanics that we have found successful in "Olympus" were those that supported players' need satisfaction of autonomy and competence. We conducted a lab experiment[39] in which we manipulated autonomy- or competence-supportive features/game mechanics. Most of these were common in commercial games, such as avatar customization, choice of how to grow strength of avatars, choices in the dialogue branching for interaction with non-player characters and narrative development, and indicators for achievements (e.g., heroism meter, achievement badges). Specifically, the autonomy- and competence-supportive mechanics facilitated the corresponding need satisfaction, which in turn resulted in greater game enjoyment, motivation for future play, game evaluation, and satisfaction.

Lukas Zimmerli: Depends on the patient population. Examples include: repetition (of movements); increasing levels; adapted level of difficulty (to capabilities of patient); exploration (e.g., using open world environments); mouse dexterity (e.g., move limb along a predefined path); jumping (e.g., open/close hand); hidden images (e.g., reveal by cleaning surface); time limits; and competition.

Brenda Wiederhold: Our therapy environments are integrated with real-time physiological responses. We have found this results not only in increased short-term effectiveness but also in promoting long-term effectiveness and lowered relapse rates. We use multiple physiological measurements (heart rate, heart rate variability, respiration, etc.) to guide progression through the therapeutic hierarchy. This allows us, combined with therapist-controlled paths and options, (1) to maximize the velocity of exposure and (2) to individualize the sessions and hierarchy for each patient and (3), most importantly, gives us an objective metric of patient performance and response that satisfies payors, such as insurance companies.

Pamela Kato: By "successful" I will assume this means that the game is engaging and also has an impact on prespecified training and educational goals. As a researcher, I feel limited in my ability to comment on specific game mechanics I have found to be "successful" because I haven't directly investigated the effects of specific mechanics and their relationship to outcomes. Outside of my role as researcher but perhaps as a blogger on games for health, I can present my personal observation that just about any game mechanic can be successful as long as it is balanced and/or supported by programming that executes it well, art that emotionally engages players, game design that promotes ongoing engagement, and content that is presented in a way that merges with all of the above seamlessly. That's not an easy task. And that is why most serious games come off as clunky, boring, pedantic, buggy, or too "serious."

Tom Baranowski: ***What kind of game mechanics have you found unsuitable for G4H?***

Debra Lieberman: There is some concern about the emotional impact of losing life in a health game, when players have a life-threatening disease such as cancer or diabetes. This is a special concern when they are playing a game that requires them to defeat the same health threats in the game that they confront in their own lives every day. Some games give the player a limited amount of life, and each time the player loses a game level or has a low score, some life is removed until, eventually, the character dies and must start the game again. This approach has been criticized for reminding players that they might die and, what's more, for implying that death in a health game is their own fault because they were not skillful enough to win. Will dying in a health game cause them to lose hope about their own battle with disease if they cannot even win a game-based battle? Research is needed to identify whether players might become fearful, pessimistic, discouraged, or depressed if they fail in a health game that deals with their own disease.

When I watch patients play games about their own serious diseases, they usually seem to be empowered and energized by the game play and glad to have a chance to fight their true enemies. They understand that failure in a game is normal and is a learning experience on the path to ultimate success. The metaphor of "dying" in a game does not seem to faze them. Their life is an epic battle, and they expect the game to be just as epic as their own health struggles. In 1995 we

designed our Super Nintendo asthma self-management game, "Bronkie the Bronchiasaurus," so that players would lose a piece of a dinosaur egg, instead of life, every time they lost a level. They had to start the level again if they lost a piece of egg, and when the whole egg (life) was gone they had to start the entire game all over again at Level 1. Young people with asthma told us it would not have mattered to them if they had lost life instead of an egg in the game. They knew that the eggs were stand-ins for lives, and either way of keeping track of game losses, by losing life or losing an egg, was fine with them. Clearly, more research is needed.

Richard Buday: It's not easy to design mechanics that are simultaneously fun, intuitively support a storyline, the player's role, and purpose in the game, and stealthily advance a G4H's serious "payload." Poor game mechanics, in serious or entertainment titles, stand out like sore thumbs. In one of our projects, players had to set health behavior goals for themselves—again, a potentially unenjoyable task. We tried a shooting gallery mechanic, hoping it would make the activity fun, but it was a poor choice. Blasting enemies makes cognitive and emotional sense in entertainment games, but shooting positive health behaviors in a G4H doesn't. Although the mechanic was fun, it worked against the health message we were trying to convey and didn't make story sense. Ultimately, the dissonance between intent and mechanic confused players.

Wei Peng: In our early prototyping and alpha testing of the "Olympus" game, we found that game mechanics that required greater gaming literacy were less successful. For instance, in "Olympus," players would need to literally walk or run on a special dance pad in order to navigate their avatars in the game world. At times players would need to look down at their feet to make sure they were oriented properly on the dance pad. During this process, the avatar was often still moving through the game world. When the player looked back to the screen, he or she would often be disoriented. Employing the typical game mechanics (e.g., mini map, visual cues) used in traditional videogames with joysticks for navigation was not successful in this active videogame. We ended up with a combination of level design techniques in the form of visual weenies and the squint test,[47,48] guiding assistance from a non-player character, the map tool, and an on-screen guiding compass to help effectively guide the players.[49]

Lukas Zimmerli: This again depends on the patient population. Examples include: Instant death (i.e., actions harming the avatar), information overload (especially for stroke patients with cognitive deficits), and competition (e.g., can also create a "negative pressure" for some patients).

Pamela Kato: Based on the above, any game mechanic that isn't implemented in a way that balances critical components of a good game that doesn't support the educational or training goals of the serious game can be considered unsuccessful.

Brenda Wiederhold: We have found that when scenarios are too complex, they often create confusion and problems with goal attainment. In our clinics we have treated patients from age 6 to age 83. It is important to increase initial training time with our more senior patients who may not be as well-versed in computer technology. It is important to use worlds that do not have bugs or glitches where the patient can get "stuck" during navigation. This may cause increased anxiety or arousal in those already suffering from an anxiety condition or stress. It is also important at all times to be cognizant of cybersickness, especially in games with increased vection (i.e., perceived self-motion from visual stimuli). Cybersickness does not necessarily mean the patient cannot continue with simulation therapy; however, therapy may require premedication with antiemetics. Other difficulties to be aware of: (1) Some elderly patients have difficulty with so many wires for peripherals, so the new wireless capabilities are really essential. (2) There are a subset of patients, such as those with seizure disorder or migraine, that require special precautions and may indeed not be able to tolerate all simulations. (3) Those with traumatic brain injury sometimes require less complexity and simulations that deliver less information with fewer stimuli. This being said, however, our studies with traumatic brain injury and PTSD have shown no negative effects on the patients using the game environment.

Tom Baranowski: ***Do you employ typical entertainment game mechanics in your G4H? If not, why not? If yes, how have they helped or hindered your games?***

Debra Lieberman: Health games must be engaging and compelling to play, and health game designers should be encouraged to use the best game mechanics in their tool kit that appeal to the target population so that people will play health games enthusiastically during leisure time. Health games should be just as entertaining, immersive, dramatic, challenging, and enthralling as commercial entertainment games. We want people to want to play them! So, yes, typical entertainment game mechanics are great in games for health. Unfortunately, health game production budgets tend to be limited. However, a skillful game designer can make a great game without a mega-budget, using many successful game mechanics found in entertainment games but without using expensive production techniques.

Richard Buday: We've learned to avoid conventional game mechanics unless they clearly support our game's gestalt and intent, including the game's behavioral and educational payloads. Common entertainment game mechanics are seductive. Tile-matching activities like "Bejeweled," fixed shooters like "Space Invaders," "Tangram" shape puzzles, or three-dimensional open worlds like "Grand Theft Auto" are obvious design ideas to crib from. They're easy to rationalize because they have been proven fun in other games and have the benefit of familiarity, which reduces the need for player instruction. But they are stumbling blocks if they don't support storylines, behavioral change, or serious topic learning opportunities. Grafting typical entertainment mechanics onto a G4H should be considered, but carefully. What entertainment developers want players to intuitively understand may not be the same as what G4H developers wish of their players. The worst thing is superimposing entertainment game mechanics on a G4H for lack of a better idea.

Wei Peng: We employed many typical entertainment game mechanics in "Olympus" to engage players. Many of them

helped the game. However, we also met some challenges to balance the entertainment game mechanics for enjoyment and for health outcomes. For instance, we included an extensive narrative in “Olympus,” which was very helpful immersing the players in the game world. However, the narrative was mainly delivered via interactive dialogues and cut scenes, during which the players did not actively move their bodies. We tried to balance the narrative to be engaging and at the same time not too long to take away the active component of the game.

Lukas Zimmerli: Yes. Such mechanics can be used to give performance feedback to patients, hence increasing their engagement. Examples include: achievements (game scores), time restrictions, and rewards and punishments.

Pamela Kato: Yes, I employ typical game mechanics in games, and I like to explore new mechanics too. A lot of people would like to have a cookbook recipe for making innovative serious games. Fortunately or unfortunately, making a serious game is a creative process involving trial and error and cooperation across disciplines.

Brenda Wiederhold: We utilize branching to allow the patient and therapist to individualize the session based on the individual patient’s needs. We have utilized all types of game mechanics. In our experience, the highest resolution and the best graphics are not always clinically necessary. What is necessary is to include the appropriate cues for the patient or trainee. The race to perfection is really not necessary here. After seeing over 800 patients (over 7000 sessions) over the past 17 years, we have found that less realistic graphics are better therapeutically. When the graphics are less specific, the patient’s brain is compelled to work harder and stay more fully engaged. This gives the patients more leeway to personalize the simulation, and they are often encouraged to fill in their own personal details. When this occurs, the experience becomes more immersive and more meaningful. For example, patients with anxiety disorders often feel out of control in the phobic scenario. The ability to personalize and master these environments in a safe setting builds self-efficacy, which is crucial for successful transfer of these skills to the real world. Another important lesson we have learned is to work closely with subspecialty consults, for example, referring patients who become cybersick to a vestibular specialist. And finally, we must always remember that simulations are only tools; they do not take the place of good clinical skills and good clinical judgment.

Tom Baranowski: ***If you developed* de novo *mechanics for your G4H, please elaborate on what, how, and why.***

Debra Lieberman: When we designed the behavioral health strategies and game mechanics for “Packy & Marlon” and “Bronkie the Bronchiasaurus,” we pushed the norms and limits, much to the consternation of the game designers. Some of our ideas ran counter to established notions about what makes a game fun and exciting. However, we had goals beyond entertainment, and our target populations had special interests and needs. Our games were designed to build self-care skills and self-confidence, enhance communication and social support, and serve as springboards for discussion between young people with a chronic condition and their friends who may not know much about the condition or may even hold misconceptions. The games were also intended to help reduce feelings of stigma that children and teens with diabetes or asthma might have. When they played a two-player version of the game with a friend, they could show off their knowledge and help their friend learn what it is like to have diabetes or asthma, and in the process see that their friend does not reject them socially for having the chronic condition. We used game mechanics that addressed those goals, as follows.

Players had to use a virtual blood glucose meter in “Packy & Marlon” and a virtual peak flow (breath strength) meter in “Bronkie the Bronchiasaurus” at the start of every game level. They also had to watch an animation of Bronkie in close-up using his inhaler correctly at the start of every game level, without being able to skip the demonstration, because our medical advisors told us that many of their patients needed to learn how to use their inhalers effectively. Our game designers warned us that these events would interfere with the flow of the game. Also, in “Bronkie” we required players to answer two multiple choice questions about asthma self-care and social situations related to asthma in each game level. They first had to find a dinosaur that gave them a question to answer correctly on the first try in order to receive an assist from the dinosaur. A correct answer boosted them or escorted them over, through, or across terrain that would have been impossible for them to traverse themselves. So, getting the question right was an essential step toward winning the game. They also had to find a second dinosaur in each game level that asked another multiple choice question, and if they answered correctly the first time, the dinosaur handed Bronkie a missing piece of the wind machine he was looking for…to save his planet from deadly dust. The game designers were not happy.

However, we conducted usability tests and play tests of prototypes of these new approaches, with the target population, to see whether our ideas were “buzz kills,” as the designers predicted, and we found instead that players with asthma or type 1 diabetes loved these game elements. They would tell us they liked the game a lot because, “This game is my life.” They never got tired of watching a close-up animation of Bronkie demonstrating proper inhaler use at the start of each game level or of checking Bronkie or Trakie’s peak flow to see whether their asthma was under control or checking Packy or Marlon’s blood glucose level before each meal or snack. This was all part of the engagement and fun, and it was behavior that was central to players’ own lives. Also, the multiple choice questions about self-care procedures and about dealing with challenging social situations related to asthma or type 1 diabetes were inherently interesting to players who also valued the questions as conversation-starters with their friends who did not have asthma or diabetes. When the games were completed and available for purchase, and many children were playing them at home and in clinics and hospitals, the unusual and potentially disrupting game mechanics continued to be extremely popular.

In the “Bronkie” game, asthma care is essential to win the game. Players must guide Bronkie and his friend Trakie (a female Tracheratops) in 18 game levels where there are asthma triggers all over the place that they have to avoid as they move through the game world. Asthma triggers include,

for example, furry animals ambling around, cigarette smoke puffs emerging randomly from mysterious dark windows, huge dust sacks strewn in Bronkie and Trakie's path and emitting billows of dust, pollen wafting from the trees, oil drips falling from above when least expected, and sneezer characters who sneeze a big blast of cold viruses every so often. Players must make sure their character does not bump into any triggers or get hit by a spray of cold viruses because the triggers reduce peak flow and cause coughing and wheezing, and thereby render the character less able to win the game. Avoiding asthma triggers is difficult and requires skillful eye–hand coordination so, when inevitably during the first attempts at game play Bronkie or Trakie bump into a trigger, players must help them take appropriate medications or help them follow their sick-day plan if cold viruses have hit. The physical act of maneuvering Bronkie and Trakie to avoid the asthma triggers is a reminder to do the same thing in daily life. Also, selecting the right medications when peak flow goes down and then seeing peak flow improve after taking meds is another way the game simulates actual asthma self-management. We used another unusual game mechanic in "Bronkie the Bronchiasaurus." The screen becomes increasingly dark each time Bronkie or Trakie bumps into an asthma trigger, in addition to the numerical decrease in peak flow and the corresponding increase in coughing and wheezing, so this visual impediment to game play motivates players to find medications and use them to avoid the darkened screen and also to nurture Bronkie and Trakie back to better health. If players fail to give their character medications and allow peak flow to drop very low, the screen becomes so dark that peak flow falls into the danger zone, and players have no choice but to call for help (by selecting the Call for Help option in the game). Calling for help is exactly what they should remember to do in response to their own serious asthma episodes.

Richard Buday: Given the hundreds if not thousands of existing game mechanics out there, I'd be hard pressed to call many of ours original. Most are inspired by something that has come before. The key is not necessarily to start with a clean piece of paper, but to create mechanics matched to their situation. If an existing idea can be freely adapted off the shelf and is well suited to the game, so much the better. More likely, a good game mechanic will be a combination of several existing ideas, refined, and then modified to suit a new purpose. *De novo* ideas can appear revolutionary, but are often evolutionary steps.

Lukas Zimmerli: I agree with Richard. We haven't created any new game mechanics *per se*. Existing mechanics are used, adapted, and deployed for the specific need.

Brenda Wiederhold: Yes, we have developed a program where the patient's real-time physiology controls the speed, content, and actions of the world. This helps the patient to learn physiological self-awareness and self-regulation. Many patients come into the clinic unaware of when they are becoming stressed physiologically or when they are relaxed. By becoming more aware, for example, patients with panic disorder learn to intervene early to successfully control and prevent panic symptoms many times. (We of course also teach them that a panic attack is not dangerous; as we have been told by multiple patients: "If I can learn that they are not dangerous, but also learn a skill set to prevent the symptoms in many attacks, this is a life changer.") This physiologically controlled world is also being tested for certain telemedicine applications currently. These physiologically driven game mechanics are extremely useful when treating patients with either beta-blockers to control heart rate or anxiolytics that supplement this clinical immersion.

Tom Baranowski: ***Have you collected evidence whether your G4H related to behavior or health change? What did you find?***

Debra Lieberman: The diabetes self-management game "Packy & Marlon"[5] and the asthma self-management game "Bronkie the Bronchiasaurus"[5] were researched in randomized controlled trials to investigate effects on health behaviors and health outcomes. Both games were made for the Super Nintendo console, which was a popular videogame console in the 1990s, and both were side-scrolling adventure games, the most popular game genre of that era. The games were designed for tweens ages 9–14 who had type 1 diabetes or asthma, but the games were played avidly by young people ages 5–18, including those who did not have diabetes or asthma. Since the games contained some text to read, they were advertised as appropriate for ages 7 and older.

We conducted an NIH-funded 6-month randomized controlled trial of "Packy & Marlon" in collaboration with Stanford Medical Center and Kaiser-Permanente.[2] Participants ages 8–16 with type 1 diabetes took home a Super Nintendo console and were randomly assigned to take home the "Packy & Marlon" videogame (treatment group) or a commercially popular entertainment videogame that contained no health content (control group). All participants were told that they could play their game at home as little or as much as they wished as long as they followed their parents' rules about when and for how long they were allowed to play videogames. This naturalistic study design did not require participants to play their game; they could play it or ignore it. After 6 months, the treatment group improved more than the control group, on average, in several ways, including (1) self-efficacy for diabetes self-care, (2) communication with parents about diabetes self-care, (3) diabetes self-care behaviors, and (4) reduction in diabetes-related urgent care and emergency visits.[2] The treatment group experienced a 77 percent reduction in diabetes-related urgent care and emergency visits, dropping from about 2.5 visits per child per year, on average, to about 0.5 visits per child per year, while the control group remained at about 2.5 visits per child per year. Participants in the treatment group and control group rated their game equally highly for enjoyment, and they reported playing their game an equivalent amount of time, about 34 hours during the 6-month period, on average, indicating that the health game was as enjoyable as a popular commercial entertainment game and was played as much as the entertainment game.

Richard Buday: We pilot tested or ran large clinical trials of most of our work. Results show our projects achieved some level of transferring health knowledge, increasing positive health behaviors, and/or decreasing negative behaviors.[12,50] Participants found their experiences enjoyable and would return for additional sessions. We believe we're on

the right track, but there is much we don't understand. The best is yet to come.

Wei Peng: We conducted a 4-week intervention using the "Olympus" game.[51] Playing this self-determination theory-supported active videogame resulted in an increase of moderate or vigorous physical activity among insufficiently active young adults compared to the control group immediately after the intervention was over. Participants who played the game with the theory-supported features also resulted in greater attendance than those who played the game without the theory-supported features.[51]

Lukas Zimmerli: Yes, different findings have already been published,[52–59] with further data collection in progress.

Brenda Wiederhold: Yes, we have done numerous pilot studies and have also completed several randomized controlled clinical trials. We find that the behavior mastered in the simulation setting does transfer over into a change in behavior in the real-world setting. In addition, while we continue to push the envelope and do research studies, we have also been successful at transitioning the protocols and simulation environments out of the lab setting and into real-world clinical practice. A few examples of studies we have completed include: PTSD, phobias, pain disorders, and pilot studies for medical training and teen smoking. Further elaboration as examples are:

- *Fear of flying*—We completed the first randomized controlled trial using simulation for specific phobias in the late 1990s. We found that by combining physiological monitoring and feedback (often called biofeedback) with simulation-assisted exposure therapy, we were able to have the highest success rate. This worked better than traditional therapy (imaginal exposure) and also worked better than simulation done without the added assistance of physiology. When we did our 3-year follow-up, we also found no relapse in those patients having received the combined therapy.
- *PTSD*—We completed the first randomized controlled clinical trial using simulation and physiology to treat patients returning from Iraq and Afghanistan who had a diagnosis of PTSD. Focus groups were held so that the end user (the returning warriors) could help our developers and clinicians to understand what stimuli was most important. Next the worlds were designed, developed, and tested in a pilot study in Southern California. Eighty percent of those completing treatment (there were no dropouts) were able to either stay on active duty in the military, or if they were separated from the military, they were able to become gainfully employed in the civilian sector. After the pilot, a controlled trial was completed, resulting also in no dropouts and in a 70 percent success rate. The use of simulation is well tolerated by the military sector, which is very familiar with simulation training, and it seems from comments made by many patients that this method of training also helped to destigmatize treatment for them. We have also done a study where the simulation therapy was performed in Fallujah. Treating patients when they have acute stress disorder and PTSD that is more recent has resulted in a success rate of 86 percent.
- *Pain management*—We have utilized simulation training to help those undergoing dental procedures and medical procedures to lessen their pain and anxiety. This has resulted in a lessening of pain medication necessary during the procedures. It has also resulted in many surgeries being done with local anesthesia instead of general anesthesia, lessening patient recovery time and cost of treatment. After these successes, we began pilot studies using simulation for those with chronic pain (fibromyalgia, migraine, and arthritis). Patients again were able to increase activities of daily living while lessening pain scores and physiological arousal indicative of pain. We have performed pilot studies porting the pain reducing simulations to cell phones, with continued pain relief achieved that is statistically significant, albeit less than when using the fully immersive pain simulations.

These same simulations have now been used as stress management tools with clinic patients [being] military personnel in theatre.

- *Panic disorder*—We performed a cross-cultural study with panic disorder patients from Italy, Korea, Canada, and California. The importance of this study was in finding that the same simulations could be effectively used in a cross-cultural setting since they were non-language based. (Other worlds, such as those employed for eating disorders, we have found do have some cultural factors that need to be modified for various patient populations.)
- *Combining virtual reality and pharmaceuticals*—We are now continuing to push the envelope by combining pharmacological agents with simulation tools. For example, a recent article we published in the *Proceedings of the National Academy of Science* reported on our use of glucocorticoids to enhance and shorten the amount of time required to effectively reduce phobic symptoms.[60]

Pamela Kato: The efficacy of "Re-Mission" was validated in a randomized trial that showed that patients who played the game showed greater adherence to antibiotics and oral chemotherapy compared to patients who played a control game. These improvements were mediated by increased knowledge and self-efficacy to manage cancer and its side effects.

Tom Baranowski: ***Our discussants have all made important contributions to the design and evaluation of G4H. Many types of game mechanics have been developed and deployed, and most have been around for a while. The discussants reported that game mechanics should be congruent with the tone and content of the game; incongruent game mechanics have led to underappreciation of the game. Entertainment industry game mechanics provide a huge pool of mechanics for consideration for use in any particular G4H, but may need to be adapted to its serious agenda. The new technology-based behavior and physiology monitors offer special promise of integrating game play with real-life experiences and challenges. Several of the discussants called for research to better identify the circumstances under which specific game mechanics might be most effective. We hope the***

***authors of those studies will consider submitting their results to the* G4HJ.**

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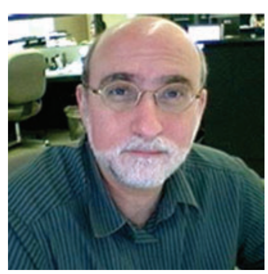
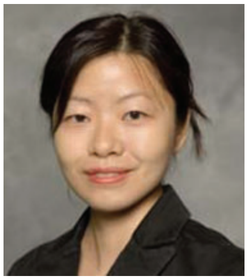
Brief Biosketches

Debra Lieberman, EdM, PhD, is a media researcher at the University of California, Santa Barbara, where she teaches in the Department of Communication. She also directs the Health Games Research national program www.healthgamesresearch.org funded by the Robert Wood Johnson Foundation to advance the research, design, and effectiveness of digital games aimed at improving health and health care. Her research focuses on processes of learning, engagement, and behavior change with interactive media, with special interests in behavioral health and the psychology of health game design. She also consults for health organizations, education agencies, and media and technology companies to improve user engagement and to help design and evaluate digital media and games for entertainment, learning, and health behavior change, for people of all ages. Debra holds an EdM (1974) in Media and Learning from the Harvard Graduate School of Education, where she worked with Sesame Street researchers and producers to develop new TV programs for children, and she holds a PhD (1986) in Communication Research from Stanford University.



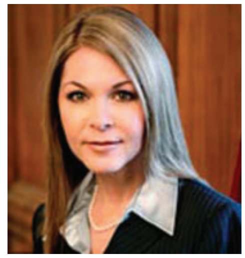
Richard Buday, FAIA, is president and founder of Archimage, a 30-year-old digital arts studio. Richard is also president of Playnormous LLC, Archimage's health education videogame company. A professional architect by training, Richard and his firm have won more than 50 international awards for design, including for broadcast television commercials; illustration and graphic design for corporate identity, magazine covers, and print advertisements; Web sites; and videogames and interactive media. Richard taught at the University of Houston for more than 15 years and has written extensively on the use of computers in design. Richard has also been invited to lecture or deliver keynote addresses at more than 70 international conferences and symposia. More than 50 articles about Richard and his firm

have been published—from *U.S. News and World Report* to *The Financial Times*. Archimage is an approved Nintendo GameCube developer. The firm's clients include Nintendo, Time Warner Communications, Compaq Computer Corporation, IBM, Knowledge Adventure, The Walt Disney Company, the Texas State Education Agency, Ziff-Davis Communications, Baylor College of Medicine, and the National Institutes of Health.



Wei Peng, PhD, is an Associate Professor in the Department of Telecommunication, Information Studies, and Media, Michigan State University. She received her PhD in Communication from the Annenberg School for Communication, University of Southern California in 2006. She is affiliated with the Games for Entertainment and Learning (GEL) lab and the Health and Risk Communication Center. Her primary research interest is to understand how to better use interactive technologies, in particular, digital games, to influence human behaviors. Her recent projects focus on using digital games for health promotion, health education, and social change. Her broader research area is the social and psychological influence of communication technology. She received funding from the Robert Wood Johnson Foundation to develop and evaluate an exergame for physical activity promotion among young adults. She has won several top article awards from the International Communication Association and the National Communication Association. She serves as a member of the editorial board of *Journal of Communication*, *Games for Health: Research, Development, and Clinical Applications*, and *International Journal of Gaming and Computer-Mediated Simulations*. Dr. Peng has 38 peer-reviewed publications, of which 23 focus on game effects and serious games.

Lukas Zimmerli, MSc, holds a Master of Science from the Swiss Federal Institute of Technology (ETH Zurich) in the field of neurosciences. He is employed as a software engineer by the medical engineering company Hocoma AG (Volketswil, Switzerland), where his responsibilities include the design and implementation of augmented performance feedback exercises for therapy. Concurrently, he pursues his doctorate studies in the field of motor rehabilitation at the Sensory-Motor Systems Lab at the Department of Health Sciences and Technology, ETH Zurich. His research interests mainly concern how games for health can be used for therapeutic purposes, improving the motivational and engaging aspects of current rehabilitation techniques.



Brenda Wiederhold, PhD, MBA, is a licensed clinical psychologist in the United States and Europe, professor at the Catholic University in Milan, Italy, and an entrepreneur. Dr. Wiederhold is the CEO of the Virtual Reality Medical Institute in Belgium and the Executive Vice-President of the Virtual Reality Medical Center in California. She completed the first randomized, controlled clinical trial to provide virtual reality medical therapy for war veterans suffering from posttraumatic stress disorder. Her most recent achievement is working with coalition troops to provide stress inoculation training prior to deployment. These are in addition to her virtual reality work since the mid-1990s with the civilian sector of patients. She works to inform and educate policymakers, funding agents, and both the scientific community and general public to advance the medical field with technology. Dr. Wiederhold is recognized as a world leader in the treatment of anxiety, panic, phobias, and posttraumatic stress disorder with virtual reality exposure and cognitive-behavioral therapy, objectively measuring results with physiological monitoring devices. She is the founder of the international CyberPsychology & CyberTherapy Conference, now in its 18th year, and the Editor-in-Chief of the MedLine-indexed *CyberPsychology, Behavior, & Social Networking Journal*. She has given invited lectures on the topic of advanced technologies and healthcare in 24 countries throughout Europe and Asia and has published more than 150 articles and 12 books on the subject.

Pamela M. Kato, EdM, PhD, is an internationally recognized expert on making serious games for health. She was the founding President and CEO at HopeLab, where she played a key role in the efforts to develop and conduct research on "Re-Mission," a widely acclaimed serious game evaluated in a multicenter randomized trial published in the journal *Pediatrics*. She recently completed "Air Medic Sky 1," an award-winning biofeedback game designed to improve patient safety among young doctors. As the owner of P.M. Kato Consulting, Dr. Kato works with international companies, government agencies, and non-profits to strategically use serious games and gamification to improve customer engagement and patient outcomes. She has numerous research publications in peer-reviewed journals. Her blog about serious games for health (http://pamkato.com) has been listed among the Top 10 serious game blogs by Pixel Learning and Online Colleges. Dr. Kato received her masters in Counseling and Consulting Psychology from Harvard University, her PhD in Psychology from Stanford University, and her postdoctoral fellowship at the Stanford University School of Medicine. Dr. Kato is a Visiting Fellow at the Serious Games Institute in Coventry, United Kingdom.

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